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LOUISIANA PURCHASE EXPOSITION
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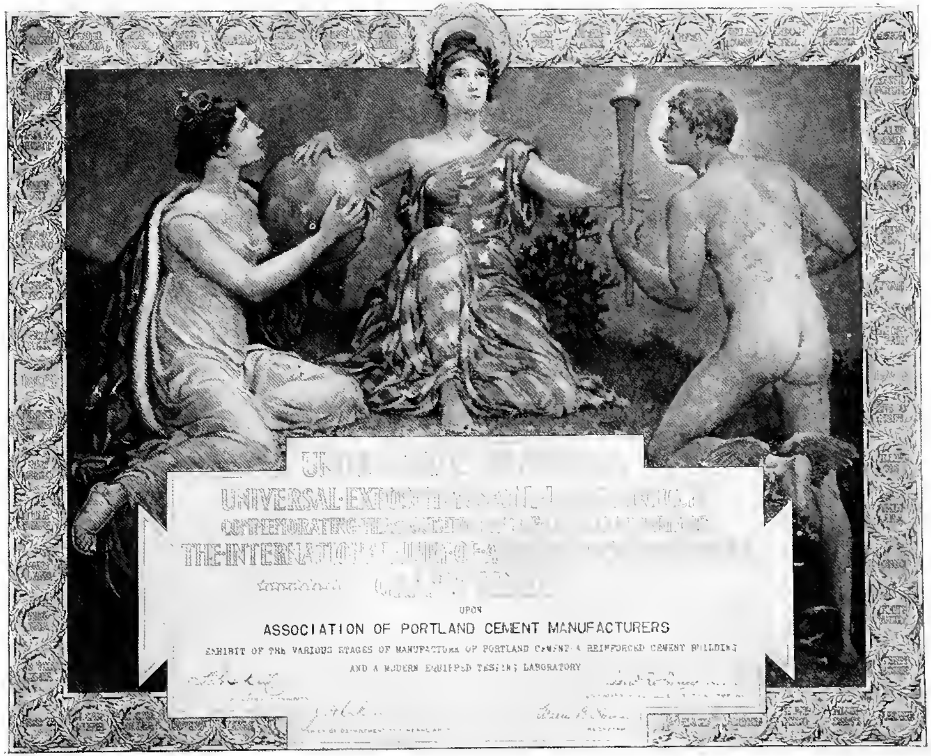


The Association of American Portland Cement Manufacturers was awarded two Grand Prizes, one for the collective exhibit and another for the model testing laboratory.

The Collective Portland Cement Exhibit and Model Testing Laboratory of the Association of American Portland Cement Manufacturers, and the Results of Tests at the Louisiana Purchase Exposition, St. Louis, Mo.*

RICHARD L. HUMPHREY, M. AM. SOC. C. E. [IN CHARGE.]

Great expositions mark the progress made in the industrial world, and emphasize the advance in particular lines. The Louisiana Purchase Exposition was no exception. Those who were fortunate in being able to attend the Exposition at Chicago in 1893 and St. Louis in 1904 doubtless observed the progress which had been made in the branches in which they were especially interested. To those interested in cement, a very noticeable feature of the former was the absence of an American Portland Cement Exhibit, and the elaborate German exhibits of this material. This was naturally to be expected at a period when American Portland cement was hardly known and was regarded as of doubtful quality, while German Portland cement was universally used and was held in very high regard. The total consumption of Portland cement in 1903 was 3,264,801 barrels, of which 82 per cent. was of foreign and only 18 per cent. of domestic manufacture. In the decade which has since elapsed a great change has taken place in the production and consumption of American Portland cement. The production has increased 450 per cent., while the importations have fallen off about 73 per cent.; the consumption now exceeds 26,505,881 barrels, and this country has grown from one of the smallest to one of the largest Portland cement producing countries of the world.

* Presented jointly to the Association of American Portland Cement Manufacturers and the American Society for Testing Materials Reprinted from the copyrighted proceedings.

It was quite appropriate that this remarkable growth of the cement industry in America should be fittingly exploited at St. Louis, and it was natural that this exploitation should be made by the American Portland cement manufacturers in a collective exhibit. Such an exhibit formed the gateway to the mining gulch of the Exposition and was one of the most attractive of the outside individual exhibits. The fact that there were no foreign cement exhibits worthy of note, served to emphasize the withdrawal of the foreign Portland cement from the American market, resulting

Fig. 1.—General View of Building.

from the development of the American Portland cement industry. In yet another particular was this collective exhibit noticeable. In 1893 the American Portland cement manufacturer, while not openly hostile to the inspection and testing of his product, was nevertheless not a strong advocate and frequently rebelled against the restrictions placed on him by the testing engineer. Yet it was because of this continual raising of requirements which compelled the manufacturer to improve his product, that he occupies a premier position in the cement industry to-day. We now find the manufacturer no longer the opponent but the firm advocate of

proper methods for testing. This new attitude was shown in the equipment and operation of the Model Testing Laboratory in which was exploited the methods for testing cement proposed by the special committee of the American Society of Civil Engineers, whose report was distributed gratuitously. Only those who have had an active part in the erection of buildings and installation of exhibits at a great exposition can appreciate the vexatious delays occasioned by unforeseen difficulties; this was particularly true of the cement exhibit.

Fig. 2.—General View of Laboratory.

It was originally intended that the work of construction should be carried on during the Exposition as a working exhibit. To secure greater advantages in an educational way it was subsequently decided to complete it as soon as possible, but before this could be accomplished the Exposition was well towards its close. The buildings, and the installation of the equipment of the laboratory and of the other exhibits were quickly completed and the whole placed in a working condition.

The completed Exhibit formed a comprehensive exposition of the Portland Cement Industry, comprising:

1. A collection of the raw materials from which Portland cement is manufactured, together with samples of this material taken in various stages of manufacture, to the finished product.

2. A collection of the various sands, gravels, cinders, broken stone and metal used in concrete, together with photographs and models of structures built of concrete in all parts of the world.

3. A library of books and files of the various technical journals devoted to cement, mortar and concrete.

FIG. 3.—View of Cement and Concrete Materials Exhibit

4. A completely equipped model testing laboratory.

5. A collection of machines for mixing and molding concrete; and,

6. A collection showing the many forms in which Portland cement is used.

The exhibit building, one of two permanent structures, which has been presented to and accepted by the Park Commission of the City of St. Louis, Mo., is an excellent example of reinforced

concrete construction, and consists of three pavilions separated by intermediate courts and connected across the front by a continuous loggia, the roof of which is covered with cement tiling (Spanish pattern) of a rich red color. This coloring, together with the red tinting of the ceiling of the loggia, relieve the general grey tone of the walls and forms an agreeable color contrast. The style, Spanish Mission, and the rough-finished walls are particularly well adapted to the use of concrete.

As much interest was manifested in the finish of the walls, a description of the method used is added. The forms were removed at the end of twenty-four hours after casting and the outside surface was then scrubbed with a soft wire brush, washing with a hose at the same time,—this removed the cement and sand from the surface, leaving the stone of the concrete prominently exposed and producing the effect of rough casting. The advantages of this method are, first the production of a uniform color, and second the prevention of the appearance of hair cracks by the removal of the excess of neat cement.

The superstructure of reinforced concrete rests on a substructure of concrete, carried to a solid foundation, reaching in some portions a depth of 16 feet. American Portland Cement, Mississippi River sand, chatts (the screened tailings from the Missouri lead mines) and broken stone were used in the concrete in proportions of one part cement, three parts sand, and six parts broken stone for the substructure, and one part cement, two parts sand, and four parts chatts for the superstructure.

The roofs, covering the pavilions, are of ferro-inclave construction, 3 in. thick; consisting of corrugated sheet iron plastered on both sides with a mixture of Portland cement and sand.

The walls are reinforced every foot, both horizontally and vertically, by $\frac{1}{4}$-in. round rods. The beams of 30-ft. span have $2\frac{5}{8}$-in. diameter round rods, in the upper and $2\frac{7}{8}$-in. rods in the lower portion. For the 20-ft. beams $\frac{1}{2}$-in. round rods are used in the upper and $\frac{3}{4}$-in. rods in the lower portion. The stirrups are $1\frac{1}{4}$-in. wide No. 16 gauge iron.

The interior walls were floated while green with a mortar of cement and sand, and subsequently tinted with rich water colors, the reception rooms being finished a deep vermilion, the laboratory a warm terra-cotta, while the exhibition room is finished in a

deep green. The ceilings are uniformly of a rich cream color. Between the windows, bordering the interior courts, are medallions of the labels of the various companies, cast in Portland cement.

The south end pavilion was used as a reception room and office, and contained a reference library of books and files of the leading technical journals devoted to cement, mortar and concrete. The north end pavilion served as an exhibit room, in which was displayed the collection of the characteristic raw materials from various parts of this country used in the manufacture of Portland cement, showing raw material in the various stages of preparation to the finished product. The coal used was also shown in the raw and finished state. In all three pavilions were transparencies of some of the Portland cement plants in this country.

The various forms of metal used in reinforceing concrete, the sand, gravel, cinders, and broken stone, from all over the country, were on exhibition. Besides, there was a collection of photographs of work built of concrete, from all over the world, and of tests made to establish the fire-resisting qualities of concrete.

The wonderful growth of the Portland Cement Industry, the steadily increasing consumption of American Portland cement, and the decreasing consumption of natural and imported Portland cement was shown graphically, while by means of maps a comparison was made between the plants in existence in 1890 and those in existence at the present time.

The central pavilion contained a thoroughly modern and admirably equipped testing laboratory, the finest that has ever been installed in this country. This laboratory was in daily operation, demonstrating the methods used for testing cement and concrete.

The mixing and molding were performed on two especially designed tables, each of which is 7 ft. long, 28 in. wide, and 3 ft. high at the main portion; each end (32 in. above the floor) has a one-inch plate-glass mixing slab 2 ft. square. In the central part of one of these tables a galvanized iron pan 2 ft. square and 6 in. deep was inserted provided with a cloth-covered wire screen top, and a wooden rack in the bottom $\frac{3}{4}$-in. high. The pan was filled with water to the top of the rack and the cloth was kept wet. The test pieces used in the determination of time of setting were

placed on this rack and kept there during the test, being removed from time to time to make trial tests of the setting. The object was to maintain the test piece under uniform conditions during the test.

The tension and compression test pieces, as well as those for the soundness, were kept in moist air for the first 24 hours after molding. For this purpose there was a moist closet, which consisted of a soapstone box 4 ft. wide, 18 in. deep and 2 ft. high resting on a wooden frame 30 in. high. The closet has a central vertical partition, and was provided with wooden doors covered with planished copper. The bottom was made water tight, and holds about 6 in. of water; the sides have cleats for holding four sets of glass shelves 4 in. wide, 22 in. long, on which were placed the molds containing the neat cement briquettes. At the bottom over the water is a wooden rack, on which were placed the molds containing the mortar briquettes.

The test pieces were removed at the end of 24 hours, marked, removed from the molds, and for all tests for longer periods than 24 hours they were immersed in tanks. These tanks were of soapstone, provided with running water and were arranged in tiers of three each. There were six tanks in all, each 6 ft. 7 in. long, 30 in. wide. One of the upper tanks is 30 in. deep, and was used for the storage of large beams and cubes of concrete; the remaining tanks were all 6 in. deep (inside measure). Each tank was provided with two inlet and two outlet pipes, by which the water was maintained at any constant level. An instantaneous gas water heater was connected to the supply so that the temperature of the water could be maintained practically at 70° F.

For the determination of time of setting and normal consistency there were two Vicat Needle apparatus, one made by Tinius Olsen and Company, and the other imported from Germany.

For the tension tests there was a long and short lever machine. The former, made and loaned by Tinius Olsen and Company, of Philadelphia, was driven by an electric motor, and was automatic in the application of the weighing load; while in the other, made and loaned by the Fairbanks Machine Company, of New York, the load was applied by a stream of shot flowing into a bucket suspended to one of the levers, the slip of the clip on the briquette being taken up by means of a worm which operates the

lower clip, a feature which has added very considerably to the value of this type of machine.

For the compression tests there was a 40,000-pound, hand-driven machine built and loaned by the Falkenau-Sinclair Machine Company, of Philadelphia, and a 200,000-pound electric motor-driven machine built and loaned by Tinius Olsen and Company, of Philadelphia. This machine was equipped with table for transverse tests up to 10 ft. clear span, and was provided with a ball and socket bed plate for compression tests up to 12 in. The former machine was new, having been built especially for this exhibit, at the request and under the supervision of the writer.

The proper way for testing cement mortars or concretes is in compression, as it approaches more nearly the conditions of actual use. When we design structures in concrete, we disregard the tensile strength of the concrete, and figure entirely on the compressive strength, incorporating in the beam or column sufficient metal to take up the tensile stresses. Why then should we test cement in tension? We will find the reason in practical rather than theoretical conditions. The average laboratory, or more specifically, the usual laboratory of the consumer, is not provided with a large fund for its equipment or operation. The usual machines used for tests of strength are the tensile testing machines, ranging in price from $90 to $200. The compression machines sell for from $800 up, besides requiring power for their operation. Their cost places these machines beyond the reach of all except the large permanent laboratories. The 40,000-pound machine, in the laboratory will sell for $300. It is to be hoped that under favorable cost conditions, compression tests will come into increasing favor, and in time supplant the unsatisfactory tension tests.

It is an encouraging fact, and worthy of note in passing, that tests of cement are being regarded of much greater importance and are receiving correspondingly greater attention than formerly. This is unquestionably the result of the increasing and varied application of cement for constructive purposes, and under conditions which render the quality of the cement of paramount importance.

The most important test that can be applied to cement is that for soundness or constancy of volume, as it is of the highest importance

that a cement once set shall remain volume-constant. No entirely satisfactory test has been devised for this purpose. In the apparatus used in this laboratory the pats were placed on a rack, over boiling water, the surface of which was kept constant by means of a constant level bottle. The pats were maintained in an atmosphere of steam at a normal pressure. No matter what the character of the water may be, the steam will be pure, and thus free from the objectionable feautres that may enter into the boiling test.

The laboratory was provided with the usual standard sieves: Nos. 100 and 200 for cement; Nos. 10, 20, 30, 40, 50, 60, 80, 100 and 200 for sands, and with an analytical balance and scales, with the necessary metric weights, made and loaned by Henry Troemner, of Philadelphia. For the specific gravity determinations the Le Chatelier's apparatus was used.

There was also a Bauschinger apparatus for measuring the expansion of cement, and the usual measuring devices for the various tests.

In the rear of the building were the outside exhibits which served to illustrate a few of the many uses to which Portland cement is put, and some of the methods employed in mixing and molding.

The flexibility of reinforced concrete construction was illustrated by a cantilever beam exhibited by the Hennebique Construction Company of New York, and which was tested to destruction as described hereafter.

Adjoining this cantilever was an exhibit of the Siegwart hollow reinforced beams, by John E. Olsen, of New York.

The Trussed Concrete Steel Company, of Detroit, Michigan, made a series of test beams and erected a floor system, the latter a combination of hollow tile and concrete beams, and also some columns supporting a beam, all serving to illustrate the "Kahn System". The tests of these beams and floor slab are also described hereafter.

A floor panel between two steel beams, resting on concrete piers, served to illustrate The Roebling Construction Company, of New York, system of fireproof flooring.

The Truss Metal Lath Company, of New York, showed a section of partition, illustrating the use of the Truss metal lath.

Ornamental work in cement was illustrated by the Algonite Stone Company, of St. Louis. The exhibit comprised a porch consisting of two columns and two pilasters, supporting a pediment and roof; these pilasters and columns were connected on each side of the porch by a balustrade. Several steps led to the porch floor. They also exhibited a Corinthian column cap, and a cap for a pilaster and other forms of artificial stone work.

The National Art Stone Company, of Chester, Pa., displayed an ornamental mantel and column; the feature of the exhibit was the extremely low percentage of cement used. Samples were exhibited containing only three, seven and ten perecent. of cement, and ninety-seven, ninety-three and ninety per cent. of sand.

The Art Mosaic Tile Company, of St. Louis, displayed mosaic work in Portland cement; they had a fireplace, a kitchen sink, and flooring tiles.

The Vulcanite Paving Company, of Philadelphia, showed a section of granolithic pavement, and a section of steel-bound concrete curbing.

Concrete railroad ties were exhibited by Casper Buhrer, of Sandusky, Ohio, and Frank Ford, of Albion, Mich. The former were made of old rails with the head bedded in the concrete and with the flange up, the latter serving as the bearing and means of holding the rail in place. They have been in service in the Lake Shore and Michigan Southern Railroad for over two years. They have also been used by a number of other railroads.

The Ford tie was in two pieces, connected by a rod insulated at the connection.

Reinforced concrete fence posts were exhibited by H. T. McCarthy, of Detroit, Mich.

The reinforced concrete burial vault, shown by George A. Rackle and Sons, of Cleveland, Ohio, marked a new feature in burial practice, having advantages over the wooden casket

The Kielberg pipe of Danish manufacture (made with a hydraulic press) was exhibited by F. L. Smith and Company of New York City, the American agents. The pipe was of excellent quality, and stood the long transportation without damage.

The hollow building block machines were exhibited by H. S. Palmer, of Washington, D. C., the Cement Machinery Company, of Jackson, Mich., and the Burlington Block Machine Company, of Burlington, Iowa. These machines were in operation daily, demonstrating the manufacture of cement blocks.

The two-piece block was exhibited by the American Hydraulic Stone Company, of Denver, Colo. Walls of various thickness from three inches and upwards were shown.

Cement brick and cement paving tile machines were operated by A. D. Mackay, of Chicago, Ill.; while cement roofing tile is displayed by the American Cement Tile Manufacturing Company, of Wampum, Pa.; Brock Bros., of St. Louis; and Furman Construction Company, of Detroit, Mich. The Brock tile is plain, the American is made corrugated, diamond-shaped and in the four-foot plain form, while the Furman is diamond-shaped.

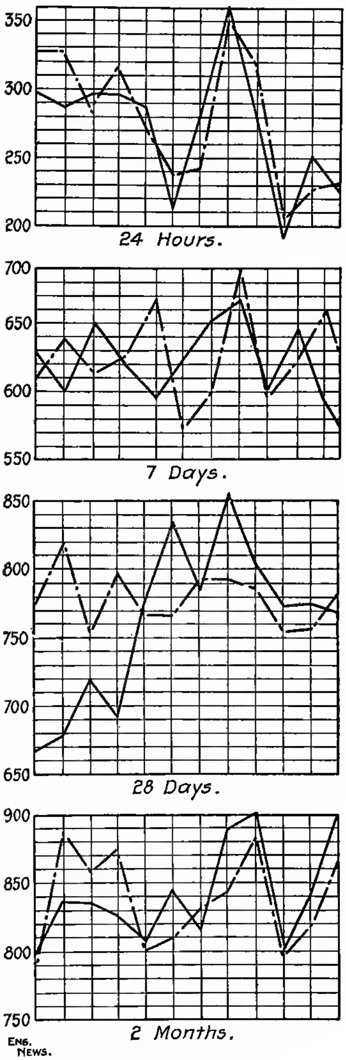
The Municipal Engineering and Contracting Company and the McKelvey Concrete Mixer Company, of Chicago, had exhibits of concrete mixers. The former was a cubical mixer, mounted on wheels, and was complete with boiler and engine for operating. The McKelvey mixer was a hand-driven barrel machine.

The limited time available after the completion of the exhibit was insufficient for the execution of any elaborate series of investigations. It became necessary, therefore, to concentrate the work on such tests as would be productive of data of the greatest value. The tests made were of two kinds: those made in the laboratory and those made among the outside exhibits, consisting for the most part of full size concrete beams and floor slabs which were loaded to destruction with pig iron. The work in the laboratory was confined to illustrating proper methods for testing cement and to investigations of the comparative value of the various sands, gravels, and broken stone used in some of the principal cities of this country.

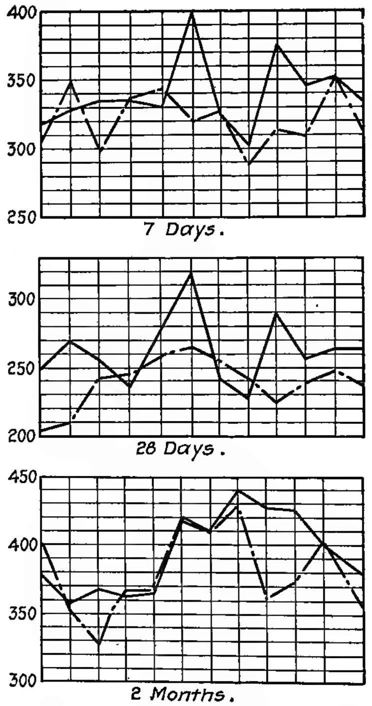
Inasmuch as the exhibit was the joint work of some forty Portland cement companies it was deemed undesirable to advertise any particular company either by permitting individual exhibits or by the use of a particular brand. The building was built with cement which was a mixture of four brands of Portland cement,

readily found in the St. Louis market. The same policy was followed in the cement used in the laboratory tests; in which case a thorough mixture was made of five brands, which gave a standard Portland cement of sufficient quantity for the entire series of tests.

It is a rather curious fact, that the average of the tests of the mixture of the five brands was higher than the average of the tests of the individual brands. The result of these tests is summarized in Table I, page 16. The variations in



Neat Cement.



Three Parts Standard Ottawa Sand.

FIG. 4.—Diagrams of Results of Tests of Cements and Mortars, Showing Effect of "Personal Equation."

the results of these tests are due to two causes: (1) Changes in the quality of the cement due to atmospheric conditions, and (2) changes occasioned by the variation in the "personal equation" of the operator. Two men made the same tests simultaneously, using similar apparatus and methods. The effect of the "personal equation" and other changes is set forth in the diagrams Fig. 4;* the ordinates being the successive tests as made, practically, at daily intervals. These men were inexperienced in the beginning and it will be noted in the diagram that while the results were far apart in the beginning they became more concordant as experience was acquired.

In the comparative tests with the standard cement, of sands, gravel, and broken stone it was only possible in the limited time to test those from the following points: Berkshire, Mass.; Cleveland, Ohio; Cowe Bay, Long Island, N. Y.; Chicago, Ill.; Dallas, Tex.; Kaw River, Iola, Kan.; Philadelphia, Pa.; Plum Island, Boston, Mass.; St. Louis, Mo.

The results of these tests will be found in Tables III, IV, V, Pl. I, opposite page 16, and diagram Fig. 5, page 17. A study of the latter is quite interesting in that it shows the relation between the size of the particles and the percentage of voids. The tests seem to indicate that the smaller this percentage the greater is the strength of the mass; this percentage being dependent on the size of the particles. Where the particles are well graded from coarse to fine, the percentage of voids is reduced to a minimum. This was found to be true of the unscreened sands and gravels, the highest results being obtained with the sand or gravel containing the least percentage of voids and showing the best gradation in the size of particles from coarse to fine.

When this material is screened to one size as 20–30 the per cent. of voids and the strength become practically the same, regardless of the strength previously obtained with the unscreened material. In this particular it apparently matters not what the geological origin of the material is, provided it is not undergoing further decomposition. It is also observable that the specific gravity of the sands and gravels is practically the same.

An examination of Table IV will show the very small percentage

*Acknowledgment is made to the *Engineering News* for the cuts used in this paper.

SAMPLE NUMBER	FINENESS IN PER CENT RESIDUE IN SIEVE		TIME OF SETTING IN MINUTES		PER CENT WATER	TENSILE STRENGTH POUNDS PER SQUARE INCH														
						NEAT									SAND					
	NO 100	NO 200	INITIAL	HARD		1 DAY	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL	7 DAYS	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL	28 DAYS	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL	7 DAYS	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL	28 DAYS	AVERAGE INDI-VIDUAL	AVERAGE GEN-ERAL
A	9.89-	26.99-	279-	510-	19½	112 121 117	116	125	532 547 550	546	535	670 684 783	712	706	166 180 170	168	160	232 260 263	249	252
A	9.15	26.90	286	436	19½	142 124 133	133		539 579 466	528		680 730 590	700		165 150 126	147		277 286 265	276	
B	8.80-	25.89-	58-	110-	20½	234 206 220	220	236	591 602 616	608	628	790 756 776	776	758	287 266 270	274	268	437 428 396	419	403
B	9.00	26.85	62	120	20½	228 272 260	250		641 650 669	658		743 721	729		259 289 244	262		387 396 380	387	
C	11.90	28.48	259-	495-	20.0	112- 107- 110	130	127	639 626 580	616	610	858 874 739	824	849	237 247 280	245	224	382 372 422	392	374
C	10.00	26.30	216	495	20.0	125 120 128	129		596 580 636	604		852 865 904	874		190 191 226	202		345 358 362	356	
D	8.99-	24.30	40-	171-	20¾	216 247 231	231	241	596 622 580	594	582	673 721 778	724	710	260 274 280	271	267	345 381 374	367	371
D	8.40	26.86	45	186	20¾	246 259 250	250		572 670 586	596		685 727 675	696		262 233 285	263		413 393 320	375	
E	4.69-	22.33	35-	265-	20½	196 196 196	196	211	542 545 597	561	553	690 670 631	664	663	220 211 208	219	202	317 336 343	332	311
E	4.10	21.60	39	280	20½	230 221 226	226		520 596 520	545		640 673 671	661		170 217 187	191		310 291 280	294	
AVERAGE	8.84	25.34	185	298	20¼		179	188	583	582		740	737		234	224		362	346	
AVERAGE	8.19	25.39	149	290	20⅛		196		580			732			213			337		
STANDARD	7.79	24.35	130	314	20.0		274	277	621	622		761	770		263	251		391	380	
CEMENT	7.75	25.60	151	332	20.0		280		623			779			240			368		

Table I.— Showing Results of Tests of Five Brands of American Portland Cement and of Samples Made From a Mixture of All Five Brands.

SAMPLE NUMBER	AGE	PROPORTION	WEIGHT PER CU. FT.	AREA	COMPRESSIVE STRENGTH IN LBS. ULTIMATE	PER SQ. IN.	REMARKS
1	60 DAYS		139.98	35.25	58500	1659	SLIGHTLY SPALLED AT EDGES.
2		1 CEMENT	143.87	35.25	59910	1700	DO.
3		1 SAND	143.10	35.15	68500	1943	DO.
4		5 CHATTS	143.87	36.00	70350	1954	DO.
5			143.36	35.33	48000	1359	DO.
6			144.06	35.63	64250	1803	DO.
AVG			143.04	35.42	61585	1740	
7	DO	1 CEMENT	143.18	35.84	29450	822	CORNERS SPALLED.
8		2 SAND	143.52	36.00	27210	759	
9		4 CHATTS	143.87	36.00	33450	929	
10			142.42	36.00	30900	858	
11			142.47	36.00	31125	865	
12			143.88	36.00	30500	848	
AVG.			143.44	35.97	30439	847	
13	DO.	1 CEMENT	146.70	34.75	30200	870	ONE CORNER SPALLED.
14		2 SAND	145.11	35.62	27880	783	
15		4 CHATTS	146.52	35.63	55250	1579	
16			147.62	36.00	49100	1364	
17			146.69	35.63	40700	1142	
18			145.73	36.00	35200	978	
AVG			146.23	35.61	39722	1119	
19	DO.		114.10	22.24	14550	654	VERY BADLY SPALLED TWO CORNERS.
20		1 CEMENT	112.90	36.00	19050	530	
21		2 SAND	113.41	33.78	15900	471	VERY POROUS SPALLED ON EDGES OF FACES.
22		4 CINDERS	112.73	35.90	22750	620	SPALLED SLIGHTLY AT EDGES.
23			113.20	33.25	19000	571	EDGES AND FACES SLIGHTLY SPALLED
24			113.72	36.00	19500	542	SLIGHTLY SPALLED
AVG			113.36	32.86	18458	565	
25	DO.		140.18	36.00	59400	1650	
26			139.97	35.20	50950	1450	
27		1 CEMENT	142.97	35.25	65650	1862	
28		2 SAND	141.80	35.25	74350	2052	
29		4 CHATTS	142.29	35.25	65250	1851	
30			140.33	36.00	588	1618	
AVG			141.10	35.49	62810	1747	

Table II.—Results of Crushing of Cubes Made From Concrete Used in Constructing Reinforced Beams.

NAME	LOCATION	SPECIFIC GRAVITY	VOIDS	FINENESS IN PER CENT OF RESIDUE ON SIEVE No. 10	20	30	40	50	80	100	200	PASSED 200	PER CENT SILT	REMARKS
BERKSHIRE	BERKSHIRE MASS	2.64	47.2	0.0	1.0	2.5	6.5	17.4	34.5	16.1	17.1	4.4	1.3	WHITE
CLEVELAND #1	CLEVELAND OHIO	2.61	31.1	41.3	21.9	13.6	9.3	6.2	4.1	1.4	1.3	1.0	5.8	BROWN
CLEVELAND #2	" "	2.66	37.9	2.2	11.4	21.7	26.3	21.5	10.2	1.7	1.1	1.3	2.6	LIGHT BROWN
COW BAY	NEW YORK	2.67	37.4	7.5	11.9	13.9	20.6	23.1	16.0	2.8	2.6	1.3	5.6	" "
JERSEY GRAVEL	PHILADELPHIA	2.66	33.2	8.0	11.0	8.6	10.1	17.6	22.3	9.9	10.4	1.8	5.2	YELLOWISH
KAW RIVER	IOLA KANSAS	2.62	31.5	10.0	16.3	15.6	15.0	15.1	19.3	8.0	2.4	0.4	TRACE	LIGHT BROWN
LIME STONE #1	ST. LOUIS MO.	2.67	35.8	6.6	28.8	14.0	8.5	6.7	6.4	3.7	4.8	20.3	21.4	WHITE
LIME STONE #2	" " "	2.67	44.0	34.7	24.4	10.6	6.6	5.0	4.3	1.8	1.5	11.3	26.3	GREY
MERAMEC RIVER	" " "	2.59	37.9	0.9	9.2	11.8	22.6	30.1	20.8	3.9	0.6	0.1	.48	LIGHT YELLOW
MISSISSIPPI RIVER	" " "	2.62	33.2	11.9	18.3	27.8	28.6	6.3	2.8	1.9	1.5	0.9	1.7	CHOCOLATE COLOR
PLUM ISLAND	BOSTON MASS.	2.66	37.5	4.5	5.6	10.8	20.2	30.7	20.8	3.8	3.0	0.7	3.8	YELLOWISH
TEXAS	DALLAS TEXAS	2.62	34.9	11.6	18.3	15.6	18.3	18.8	13.1	2.5	1.3	0.5	6.7	YELLOWISH BROWN
BANK WASHED TORPEDO	CHICAGO ILL.	2.67	29.6	19.5	16.8	9.5	10.6	14.6	15.8	6.4	5.6	1.2	3.5	" "
LAKE TORPEDO	" "	2.66	34.2	9.8	10.2	9.6	11.4	20.3	29.7	6.2	2.3	0.3	1.8	YELLOWISH
BANK SAND	PHILADELPHIA	2.64	41.8	0.9	1.8	6.1	30.1	40.4	17.1	2.3	0.9	0.3	1.9	BROWN
AVERAGE		2.65	36.5	11.3	13.8	12.8	16.3	18.3	15.8	4.7	3.8	3.1	5.9	AVERAGE

TABLE III.—Specific Gravity, Percentage of Voids and Granulometric Composition of Various Sands for Cement Mortar.

TENSILE STRENGTH IN LBS. PER SQUARE INCH

NEAT

NAME	1 DAY	AVERAGE INDIVIDUAL	AVERAGE GEN.	7 DAYS	AVERAGE IND.	AVERAGE GEN.	28 DAYS	AVERAGE IND.	AVERAGE GEN.	2 MOS.	AVERAGE IND.	AVERAGE GEN.
BERKSHIRE "	228 232 221 233 236 230	227 233	230	551 526 605 608 608 584	561 600	581	768 772 770 780 792 786	770 783	776	858 914 854 863	806 865	867
CLEVELAND #1 "	375 351 314 290	363 352	358	567 674 663 651 675 705	568 650	679	860 842 864 831 811 735	835 752	824	651 884 825 844	888 842	865
CLEVELAND #2 "	275 298 306 334	263 315	301	633 588 580 556 575 648	601 594	598	815 768 810 782 781 800	805 788	797	810 851 894 873	901 884	863
COW BAY " "	286 307 306 270	297 288	293	624 651 632 635 620 578	650 612	631	761 752 645 762 745 763	716 753	736	845 823 849 872	834 859	846
KAW RIVER	257 250 228 230	253 225	241	555 568 624 655 640 583	596 560	627	712 840 777 723 771 775	776 758	767	828 834 813 824	841 819	830
LIMESTONE #1. "												
LIMESTONE #2. "												
MERAMEC "	292 285 323 333	289 328	309	654 585 612 603 633 682	600 639	620	675 712 650 832 806 810	678 819	749	829 840 858 872	835 886	861
MISSISSIPPI "	302 293 309 347	299 328	314	663 610 621 583 571 669	628 608	616	604 580 717 730 785 708	667 772	720	788 807 863 705	798 784	791
PLUM ISLAND " "	276 286 241 245	262 243	263	672 646 640 591 570 639	653 600	626	768 832 753 755 798 824	784 792	788	798 831 818 844	814 831	822
TEXAS "	195 100 205 206	193 206	199	642 639 654 616 675 372	645 621	633	783 788 790 783 730 732	778 758	764	788 806 778 793	801 786	799
WASHED BANK TORPEDO	286 253 261 283	265 272	281	595 546 649 613 643 715	597 658	628	770 778 772 764 756 732	777 768	773	800 812 807 793	806 805	803
LAKE TORPEDO " "	275 320 333 302	297 318	308	571 630 638 568 541 641	620 617	619	834 680 760 803 802 790	683 798	746	834 816 878 872	828 874	880
AVERAGES		274 280	277		621 623	622		781 779	770		641 638	640

STANDARD OTTOWA SAND

NAME	7 DAYS	AVERAGE IND.	AVERAGE GEN.	28 DAYS	AVERAGE IND.	AVERAGE GEN.	2 MOS.	AVERAGE IND.	AVERAGE GEN.
BERKSHIRE "	228 280 284 251 243 262	264 239	232	386 387 380 360 373 365	384 363	374	428 433 396 414	431 405	418
CLEVELAND #1 "	232 228 224 235 238 234	228 243	234	347 343 365 349 304 332	352 328	340	338 393 369 391	391 380	366
CLEVELAND #2 "	285 291 290 215 220 231	289 225	257	460 431 392 363 353 373	428 364	396	472 485 352 431	475 412	446
COW BAY " "	246 240 286 260 239 227	257 242	250	410 375 344 366 327 388	384 347	360	425 412 393 372	419 378	398
KAW RIVER	265 261 265 259 254 231	264 248	256	396 387 420 385 419 402	407 402	401	444 458 447 442	451 465	453
LIMESTONE #1. "									
LIMESTONE #2. "									
MERAMEC "	273 262 276 203 208 220	270 210	240	390 363 382 404 417 386	378 399	389	405 402 390 412	408 401	405
MISSISSIPPI "	240 252 256 192 195 223	249 203	224	366 346 393 350 362 342	368 351	360	416 437 468 441	428 455	442
PLUM ISLAND " "	232 236 237 251 255 285	242 255	249	341 390 397 384 378 370	378 377	377	462 499 466 454	481 460	461
TEXAS "	260 277 240 218 246 253	259 240	250	445 373 372 358 363 363	358 340	379	466 487 422 427	477 425	451
WASHED BANK TORPEDO	262 275 285 240 242 262	275 258	265	378 363 400 357 310 410	380 392	386	401 432 420 418	415 418	417
LAKE TORPEDO " "	238 244 233 247 252 231	237 243	240	378 373 398 412 375 372	385 386	386	410 418 432 356	414 416	415
AVERAGES		263 240	281		391 368	380		437 423	430

UNSCREENED SAND

NAME	7 DAYS	AVERAGE IND.	AVERAGE GEN.	28 DAYS	AVERAGE IND.	AVERAGE GEN.	2 MOS.	AVERAGE IND.	AVERAGE GEN.
BERKSHIRE "	139 136 188 138 120 122	138 127	133	215 216 224 200 210 214	218 208	213	298 286 276 254	292 285	289
CLEVELAND #1 "	296 302 266 221 228 235	288 229	255	349 343 360 300 291 340	351 310	331	368 355 372 344	381 355	370
CLEVELAND #2 "	220 225 227 188 198 286	223 194	209	320 370 320 340 330 330	337 336	337	401 362 382 356	381 369	375
COW BAY " "	278 251 249 244 250 235	298 243	251	341 373 353 334 318 329	356 324	341	362 381 330 336	372 333	353
KAW RIVER	302 251 275 264 240 266	289 257	272	340 355 329 336 380 360	341 359	350	386 372 358 397	379 378	375
LIMESTONE #1. "	295 237 306 255 220 242	298 246	273	372 370 365 402 360 433	369 406	389	338 391 458 484	393 444	420
LIMESTONE #2. "	260 273 256 195 243 237	256 232	244	365 360 365 450 447 452	363 450	407	480 498 520 510	489 515	502
MERAMEC "	260 270 290 224 232 233	243 230	247	315 380 351 278 280 298	352 286	315	377 376 360 322	377 341	358
MISSISSIPPI "	280 240 241 240 260 243	244 248	246	333 347 328 332 320 314	334 322	328	360 347 324 347	354 337	345
PLUM ISLAND " "	200 182 218 180 185 183	300 183	192	252 225 248 202 220 211	242 211	227	335 348 298 301	341 299	320
TEXAS "	360 303 322 252 254 262	328 258	256	449 420 415 387 323 403	428 404	416	481 407 446 461	469 454	442
WASHED BANK TORPEDO	360 340 300 244 253 243	317 247	282	478 420 352 343 332 352	430 363	397	438 444 398 418	441 408	423
LAKE TORPEDO " "	298 356 317 238 278 252	317 263	219	399 401 391 381 387 389	397 389	393	425 433 410 412	431 411	421
AVERAGES		260 224	243		342 336	338		389 377	385

SAND SCREENED TO 20–30

NAME	7 DAYS	AVERAGE IND.	AVERAGE GEN.	28 DAYS	AVERAGE IND.	AVERAGE GEN.	2 MOS.	AVERAGE IND.	AVERAGE GEN.
BERKSHIRE "									
CLEVELAND #1 "									
CLEVELAND #2 "	241 240 220 208 198 232	235 213	224	287 280 310 303 345 251	292 318	308	319 337 352 343	328 386	343
COW BAY " "	210 227 210 199 212 222	216 217	217	257 298 290 301 319 295	294 305	299	316 306 317 315	312 316	314
KAW RIVER	243 256 252 270 260 284	250 261	256	341 366 358 350 327 362	361 346	358	394 401 382 375	398 379	389
LIMESTONE #1. "	257 233 240 212 247 235	243 232	238	298 281 287 321 322 305	288 316	302	316 318 328 346	317 337	327
LIMESTONE #2. "	210 206 212 241 238 218	209 231	220	295 331 312 346 315 302	319 321	320	341 318 329 333	330 331	331
MERAMEC "	213 209 212 228 238 242	211 243	227	283 292 303 302 283 284	292 290	291	337 310 309 322	324 315	320
MISSISSIPPI "	215 216 215 211 198 221	219 213	216	298 301 307 292 283 298	302 290	296	336 328 323 329	332 327	329
PLUM ISLAND " "	210 213 235 250 226 217	219 231	225	290 314 295 322 309 316	300 317	309	321 337 343 352	329 348	339
TEXAS "									
WASHED BANK TORPEDO	251 254 260 206 223 220	255 216	236	324 340 328 274 290 292	331 285	308	363 341 309 337	352 323	338
LAKE TORPEDO " "	212 220 227 223 231 243	220 239	230	302 312 317 308 313 314	310 311	311	335 351 330 327	346 328	334
AVERAGES		225 229	227		302 308	305		370 371	371

TABLE IV.—Comparative Tensile Strength of Mortars Made of Sands of the Composition Shown in Table II.

COMPRESSIVE STRENGTH IN LBS. PER SQ. INCH

NAME	OTTOWA STANDARD 7 DAYS		28 DAYS		2 MONTHS		UNSCREENED 7 DAYS		28 DAYS		2 MONTHS		SCREENED TO 20–30 7 DAYS		28 DAYS		2 MONTHS	
BERKSHIRE "	1425 1655 1540 1225 1275 1250	1395	2428 2325 2377 2250 2393 2323	2350	2275 2213 2244 2275 2223 2250	2247	700 666 694 388 390 389	542	863 1000 932 950 838 894	913	1500 1545 1523 1490 1498 1494	1506						
CLEVELAND #1 "	1275 1280 1278 1250 1260 1255	1267	2758 2653 2706 1725 1775 1750	2228	3440 2955 3198 2295 2775 2535	2867	1458 1475 1467 1043 1388 1215	1341	1885 2055 1970 1425 1350 1388	1679	3025 2523 2774 2313 2478 2396	2572						
CLEVELAND #2 "	1308 1265 1297 1275 1375 1325	1311	2208 2225 2217 2138 2113 2126	2171	2463 2680 2572 2275 2388 2331	2452	938 925 932 1200 1200 1200	1066	1695 1688 1692 1400 1300 1350	1521	2850 2668 2757 2453 2488 2468	2613	1105 1270 1189 1185 1125 1155	1172	2300 2250 2275 2200 2413 2307	2291	2428 2450 2464 2475 2565 2520	2492
COW BAY " "	2885 2703 2794 1225 1343 1294	2039	3513 3738 3626 2688 2800 2744	3185	4038 3975 4007 3450 3563 3507	3757	2080 2175 2108 1019 1303 1161	1632	2888 2825 2856 2413 2025 2238	2547	3578 3390 3484 2800 2778 2789	3137	1620 1550 1585 1473 1533 1503	1544	2350 2378 2364 2493 2488 2491	2428	2380 2363 2372 2828 2795 2812	2592
KAW RIVER "	1300 1227 1263 1698 1608 1653	1456	2138 2125 2131 1950 2000 1975	2053	2540 2463 2502 2478 2450 2464	2483	1495 1475 1485 1658 1500 1594	1540	2463 2175 2319 1900 1863 1882	2100	2415 2575 2495 2283 2218 2251	2373	1300 1448 1374 1363 1300 1332	1353	2363 2275 2319 2675 2063 2369	2344	2410 2428 2419 2528 2488 2508	2464
LIMESTONE #1 "	1380 1353 1367 1420 1403 1412	1389	2188 2178 2163 2275 2235 2255	2219	2658 2530 2594 2895 2793 2844	2719	2618 2550 2582 2663 2400 2532	2557	3313 3438 3376 3238 3850 3544	3460	2715 3628 3672 3775 3695 3735	3704	1425 1398 1412 1213 1150 1182	1297	2300 2038 2169 2225 2186 2207	2188	2343 2450 2397 2178 2173 2176	2287
LIMESTONE #2 "							958 935 947 975 1150 1163	1005	1113 1186 1150 1375 1575 1475	1313	1625 1678 1652 1835 1670 1753	1703	1053 1083 1067 1113 1128 1121	1095	1944 2225 2085 2000 2025 2015	2050	2223 2075 2149 2063 2075 2069	2109
MERAMEC "	1725 1625 1475 1250 1275 1263	1369	2975 2883 2929 2638 2563 2601	2765	3665 3575 3619 3300 3075 3188	3403	1275 1378 1325 1200 1150 1175	1250	2275 2315 2295 1770 1705 1738	2017	2300 2363 2332 2425 2288 2357	2345	1225 1288 1257 1230 1218 1224	1241	2123 2000 2062 2158 2270 2214	2138	2450 2478 2464 2438 2432 2435	2450
MISSISSIPPI "	1155 1216 1186 1358 1250 1302	1244	2723 2670 2697 3213 3575 3394	3046	2938 3125 3062 3625 3250 3688	3375	1553 1583 1568 1450 1488 1469	1519	3803 3748 3776 3420 4125 3773	3775	3875 4138 4006 4675 4413 4544	4275	1088 1000 1044 950 1050 1000	1022	2410 2538 2474 2460 2748 2604	2539	3863 3888 3876 2713 2600 2657	3016
PLUM ISLAND " "	1368 1368 1468 1500 1400 1450	1459	2475 2668 2581 2388 2275 2332	2457	3046 3263 3154 2785 2725 2755	2954	1154 1038 1096 1013 968 991	1043	1635 1518 1577 1600 1500 1550	1564	2750 2495 2623 2533 2468 2501	2562	1208 1238 1223 1193 1205 1199	1211	2253 2203 2227 2453 2054 2254	2241	2718 2930 2828 2600 2560 2580	2704
TEXAS "	1203 1240 1223 930 1095 1013	1118	2188 2510 2349 2075 1930 2003	2176	3163 2820 2992 2478 2690 2584	2788	1300 1233 1267 1500 1748 1624	1446	1725 1928 1827 3138 2308 2673	2250	2378 2405 2392 3538 2475 3006	2699						
WASHED BANK TORPEDO " " "	1195 1083 1139 1055 1280 1168	1153	3380 2700 3040 2313 2675 2494	2767	3880 3593 3737 2675 2750 2713	3225	1413 1355 1384 1723 1725 1724	1554	2613 2280 2447 3150 3600 3475	2961	3158 3145 3152 3150 2800 2975	3064	1113 1000 1057 1180 1125 1153	1105	2260 2400 2330 2350 2522 2436	2383	2910 2870 2990 2860 2848 2850	2897
JERSEY GRAVEL	1758 1695 1727 1200 1070 1135	1431	3705 3480 3593 2650 2575 2613	3103	3900 3938 3919 3093 3428 3262	3590	1000 1143 1072 955 1108 1032	1052	1863 1643 1753 1625 1363 1494	1626	2385 2428 2407 2208 2235 2222	2315	1153 1178 1166 1145 1115 1130	1148	2163 2260 2212 2075 2178 2126	2169	2453 2488 2471 2315 2328 2322	2397
PHILA. BANK SAND " " "	1180 1220 1200 1088 950 1019	1105	2408 2525 2467 2308 2328 2318	2392	2750 2718 2734 2540 2498 2519	2626	503 488 496 450 458 453	475	1038 1020 1029 778 763 771	900	1713 1775 1744 1483 1543 1513	1629	700 550 625 495 558 527	577	1063 993 1028 1190 1203 1197	1114	2038 2020 2029 1990 1968 1979	2004
AVERAGE		1364		2532		2960		1288		2045		2607		1161		2171		2492

TABLE V—Comparative Compressive Strengths of Mortars Made of Sands of the Compositions Shown in Table II.

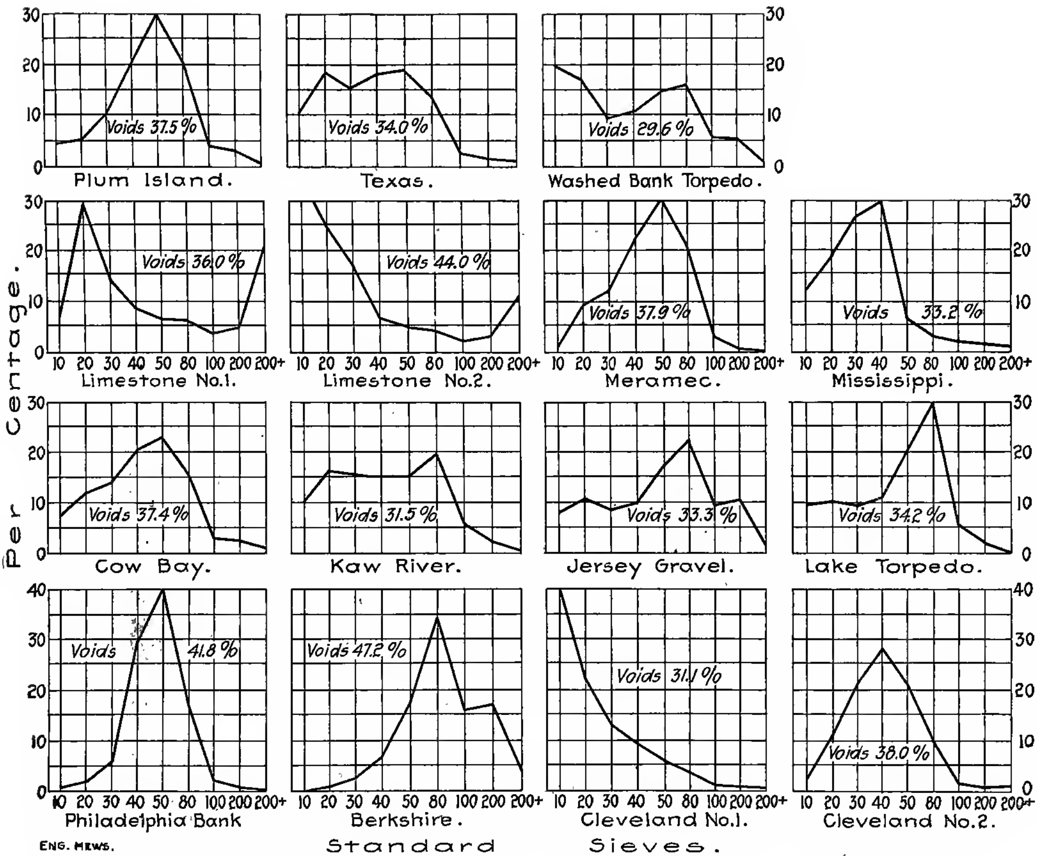


FIG. 5.—Diagrams Showing Granulometric Analysis of Various Sands for Cement Mortars.

of fine material passing the number 200 sieve and even of material designated as "silt" except in the case of the two limestones. This fine material in all cases being inorganic, and should not, therefore, be classed as "loam"—a term in common use. The term "loam" is a much abused one, is rarely ever used correctly, as "loam" properly so called is a vegetable mold and has a decided weakening effect on the strength of any material in which cement is used as a binder. Fine inorganic material, if not present in excessive proportion, enhances the strength of mortars or

Fig. 6.—Views of Reinforced Concrete Beams 1, 2, 3 and 4 After Failure.

concretes, as it tends to lessen the percentage of voids thereby reducing the quantity of cement required to fill the voids.

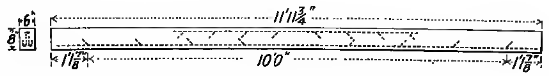
In addition to the above tests, four experimental beams were tested in the laboratory; three of these (two of rectangular and one of T-section) were made according to the Hennebique system; and the other, also rectangular in section, according to the Kahn system. The beams of rectangular section were made under identical conditions and were designed to carry the same load using the same percentage of steel reinforcement. These beams were made in the open air and were not wetted after being made

and the forms were removed just before the tests were made, at the end of 60 days. The beams remained in the open air during that time and were not moved until tested.

Test cubes were made of the concrete from which the beams were cast and the results of these tests may be found on page 16, Table II from 25 to 30 inclusive.

Fig. 6 shows the condition of the beams after testing; the photographs are not, however, sufficiently clear to show the location of the hair cracks. The poor quality of the concrete which will be alluded to later, caused the beams to fail without developing the full strength of the steel in tension, although in both the Hennebique and Kahn beams the compressive resistance of the top of the beam was materially increased by the steel reinforcement. In the latter beam the results would probably have been higher had the top reinforcing bar run the full length of the beam, as it will be observed that the concrete failed around the ends of this bar.

The following is the result of the tests of these beams in the order in which they were tested:

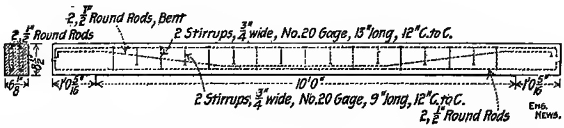


BEAM 1, KAHN SYSTEM.—Length over all, 11 ft. 11¾ ins.; clear span, 10 ft.; breadth, 6¼ ins.; depth over all, 8½ ins.; depth to center of steel, 7½ ins.; compressive strength concrete, 60 days, 1,747 lbs. per sq. in.; weight of beam, 593 lbs.; mixture, 1 : 2 : 4; reinforcement in top, one ½-in, Kahn bar 9 ft. long; reinforcement in bottom, two ½-in. Kahn bars 11 ft. 11¾ ins. long.

Steel in tension	1.59%
Steel in compression	.80%
Total steel	2.39%

Loads. lbs.	Deflection. in.	Remarks.
1350	3-32	
2350	1-8	
3350	5-16	Crack appeared on right under end of top of reinforcing bar.
4350	3-8	
5350	15-32	Crack appeared on left under end of top of reinforcing bar.

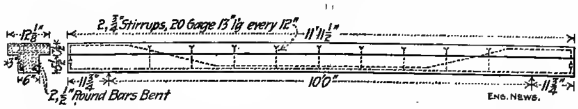
Loads. lbs.	Deflection. in.	Remarks.
6350	17-32	
7350	5-8	
7770	7-8	Failed by concrete crushing around ends of top reinforcing bar. Concrete buckled at the ends of top bar.
7830		



Beam 2, Hennebique System.—Length over all, 12 ft. 5/8 in.; clear span, 10 ft.; breadth, 6⅛ ins.; depth over all, 8½ ins.; depth to center of steel, 7½ ins.; weight of beam, 620 lbs.; mixture, 1 : 2 : 4; compressive strength of beam, 60 days, 1,747 lbs. per sq. in.

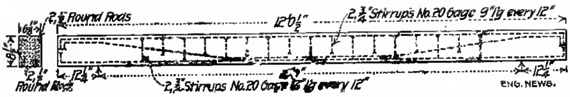
Steel in tension	1.60%
Steel in compression	.80%
Total steel	2.40%

Loads lbs.	Deflection in.	Remarks.
1850	3-32	
2350	1-8	
4350	5-16	
5350	7-16	
6350	9-16	Hair cracks appeared on either side of center, very faint.
7650	13-16	
8150	15-16	Cracks became more general.
8450	1–13-16	Failed by concrete buckling in center of beam.



Beam 3, Hennebique System.—Length over all, 11 ft. 11½ ins.; clear span, 10 ft.; breadth, 12⅛ ins.; depth over all, 9 ins.; depth to center of steel, 7½ ins.; weight of beam, 876 lbs.; mixture, 1 : 2 : 4; strength of beam, 60 days, 1,747 lbs. per sq. in.

Loads. lbs.	Deflection. in.	Remarks.
2350	1-8	
4350	5-32	
6350	3-8	
7950	15-32	First hair cracks appeared in center.
8350	9-16	
8750	7-8	Failed by concrete crushing at top in center of beam.



BEAM 4, HENNEBIQUE SYSTEM.—Length over all, 12 ft. ½ in.; clear span, 10 ft.; breadth, 6⅛ ins.; depth over all, 8½ ins.; depth to center steel, 7½ ins.; weight of beam, 614 lbs.; mixture, 1: 2: 4; compressive strength, 60 days, 1,747 lbs. per sq. in.

Steel in tension	1.60%
Steel in compression	.80%
Total	2.40%

Loads lbs.	Deflection. in.	Remarks.
1350	1-16	
2350	1-8	
3350	3-16	
4350	7-32	
5350	3-8	
6350	1-2	Faint hair cracks on either side, center very faint.
7350	19-32	
8350	13-16	
8650	1	Failure by concrete buckling at top in center.

An average of several tests of the ½ inch round rods used in beams 2, 3 and 4 is as follows:

Elastic limit 41,500 lbs; modulus of elasticity 28,000,000; ultimate strengh 60,500 lbs.; elongation in 8 inches 25%: reduction of area 61%; fracture, angular, silky, blueish-grey color: surface pitted and rusty.

In the space adjacent to the Exhibit building there had been planned an elaborate series of test beams built according to the various systems in use in this country. Unfortunately, the exhibit was completed so late that it was impossible to stir up sufficient interest to carry out an elaborate program. Besides, there were no funds available for such experiments, and the expenses connected with the tests which were made were very generously borne by the Trussed Concrete Steel Co., of Detroit, Mich., and The Hennebique Construction Co., of New York, to whom the writer wishes to express his thorough appreciation and thanks for the interest taken and the assistance rendered by them in the experiments.

The tests in question consisted in reinforced concrete beams and floor slabs of 15 ft. span and a cantilever. Simultaneous with the making of the test beams 6-in. cubes were made from the concrete which was used in making the beam and floor slabs. The results of these tests are found in Table II, page 16.

The chatts which were used were a calcareous chert, all of which passed a No. 10 screen. There are two varieties of chatts, a hard silicious chert which comes from Joplin, Mo., and the soft calcareous chert which comes from Bonne Terre, Mo. This material is the refuse from the lead mines and as it is relatively cheap it is extensively used in St. Louis and vicinity. The chatts used was of the calcareous variety and were quite soft and friable, having a low compressive strength and therefore making a concrete correspondingly poor.

It was for this reason that the beams tested failed in many cases under a small load before the strength of the steel was developed.

It will be noted that the cinder concrete gave correspondingly low results. The cinder was clean and of a better quality than is generally used—although it contained a large quantity of unburned coal. The strength of the concrete in which it was used was about one-half of that of a good stone concrete. The modulus of elasticity was about 1,500,000 in the concrete made with chatts and 500,000 for the cinder concrete—values materially lower than are usually quoted.

These tests show how important it is to have a hard aggregate in order to secure a strong concrete. An important feature generally overlooked in tests of concrete is the compressive strength of the aggregate itself. If a test of the aggregate was made it would serve as a basis for comparing the compressive resistance of concrete and would indicate whether the difference was due to differences in the strength of the aggregate or was due to the mixing or to character of the other aggregates.

The concrete for the beams and floor slabs was mixed by hand in the proportion of one part Portland cement, two parts Mississippi River sand and four parts chatts; wooden forms were used and were thoroughly wetted before the sloppy wet concrete was deposited in them. The concrete was not subsequently wetted and the forms were removed at the end of ten days. They remained in air, unprotected, and were not handled until tested at the end of about 60 days, when they were loaded to destruction with pig iron. This method is a slow, laborious process requiring the exercise of great care in loading so as to maintain the center of gravity of the load over the center of the beam, but there were no

other means available for testing these beams of such large size and span.

The overturning which occurred in the case of A and B was produced by the unequal compression of the earth under the bearings supporting the beams. Possibly, this will also account for the shearing of the overhanging un-reinforced slab in the T beam F. The ground on which the beams were built had been filled in with the refuse staff, scaffolding, etc., from the Exposition buildings and in proportioning the bearing area insufficient allowance was made for the compressibility of this filling.

In order to avoid arching of the pig iron, through the deflection of the beam under load, the pig iron was placed in piles and sufficient clearance was left between the piles so that the deflection would not bring them into contact. Where the load required to break the beam is large, these piles are quite high (for A and B they were 5 ft.), the piling of the pig becomes slower and the maintenance of the equilibrium much more difficult as the height increases. The rate of loading varied from 50 lbs. to 150 lbs. per minute. The deflections were measured at the center from a string stretched taut over two wire nails in the side of the beam immediately over the edge of the support and in the center line of the bottom reinforcing steel.

The following are the results of the tests of these beams:

BEAM F.—Built Sept. 13; tested Dec. 1, 1904. Length over all, 17 ft.; clear span, 15 ft.; breadth at base, 8 ins.; at top, 18 ins.; depth over all, 13½ ins.; depth to center of steel, 11½ ins.; reinforcement in bottom, two 1-in. round bars, with one 1-in. round bar just above; mixture, 1:2:4; weight of beam, 2,529 lbs., compressive strength of concrete, 1,740 lbs. per sq. in., per cent. of steel, 1.63, area of steel, 2.35 sq. ins.

Time.	Loads. lbs.	Deflection. in.	Remarks.
10.50 A. M.	3656	3-16	
11.35 "	6877	3-16	
11.50 "	8997	1-4	
12.00 Noon.	10807		
1.05 P. M.	14105	7-16	
1.40 "	18898	9-16	Two hair cracks 1 ft. off center line either side
	20166		Failed.

Bars sliding as beam collapsed, Fig. 7. The slab sheared off on one side as will be seen, this was probably due to lack of uniformity of

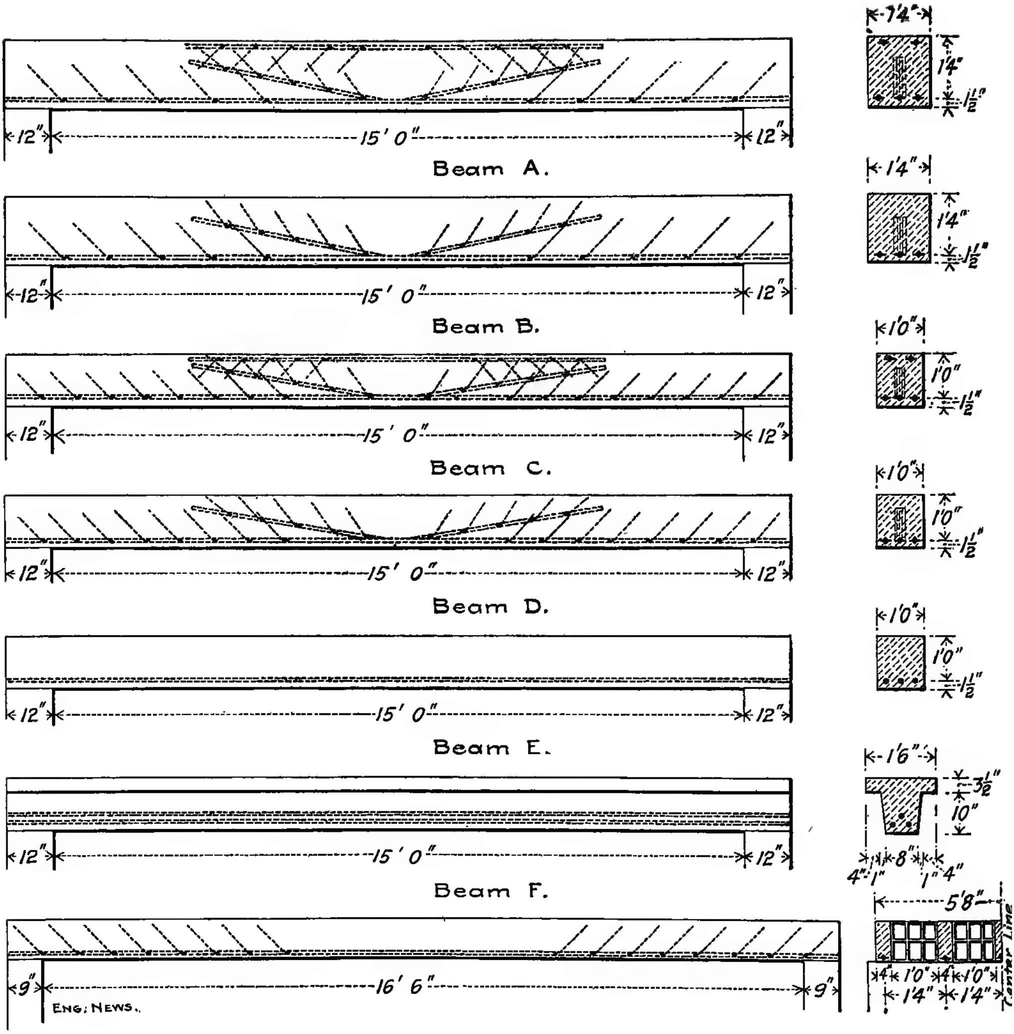


Fig. 8.—Diagrams of Test Beams and Floor Slab Showing Dimensions and Reinforcement.

load. The bars did not slip until the beam collapsed There was no reinforcing in the slab. The dimensions of beam and other information can be obtained from Fig 8, page 24.

BEAM E.—Built Sept. 13; tested, Dec. 1, 1904. Length over all, 17 ft.; clear span, 15 ft.; breadth, 12 ins.; depth over all, 13½ ins.; depth to center of steel, 12 ins.; weight of beam, 2,677 lbs.; mixture, 1:2:4;

FIG. 7.—View of End of Beam E Showing Shearing Off of Slab and Sliding of Reinforcing Rods.

compressive strength of concrete, 1,740 lbs. per sq. in.; reinforcement in bottom, three 1-in. round bars 17 ft. long; area of steel, 2.35 sq. ins.; per cent, 1.63.

Time.	Loads. lbs. sq. in.	Deflection. in.	Remarks.
9.00 A. M.	16510	9-32	Deflection not noticed before 1,000 lbs.
12.00 Noon.	20166	11-32	
	24612	15-32	
5.30 P. M.	26460	1-2	

Time.	Loads lbs. sq. in.	Deflection. in.	Remarks.
Dec. 2d.			
8.30 A. M.	33198	21-32	
8.30 "	26460	11-16	Two hair cracks, one on either side of the center line.
	33108		Failed.

A series of vertical cracks appeared until the beam failed suddenly by horizontal shear at one end entirely. Bars again slipped as beam collapsed. Dimensions of beam given in Fig. 8, page 24. Fig. 9 shows beam after failure.

Dimensions, etc., see Fig. 8.

FIG. 9.—View of End of Beam E Showing Sliding of Reinforcement.

BEAM D.—Built Sept. 13; tested, Dec. 2, 3, 1904; Length over all, 17 ft.; clear span, 15 ft.; breadth, 12 ins.; depth over all, 13½ ins.; depth to center of steel, 12 ins.; weight of beam, 2,677 lbs.; mixture, 1:2:4; reinforcement in bottom, two ¾-in. Kahn bars 17 ft. long; reinforcement in bottom, one ¾-in. Kahn bar 9 ft. long, bent up slightly; area steel in tension, 2.34 sq. ins.; per cent. of steel, 1.63; compressive strength of concrete, 1,740 lbs. per sq. in.

Time.	Loads. lbs.	Deflection. ins.	Remarks.
Dec. 2d.			
3.30 P. M.	6479	1-16	
3.50 "	8461	3-32	
5.00 "	11806	1-4	
5.30 "	15033	11-32	
Dec. 3d.			
8.30 A. M.	15033	11-16	
8.55 "	20732	3-8	
9.30 "	23476	1-2	
10.30 "	27800	11-16	
11.30 "	30719	1 in.	
11.45 "	32663	1¾ in.	
11.50 "	32663		Failed slowly 4 ft. 6 ins. from each end of beam.

Dimensions, etc., see Fig. 8.

BEAM C.—Built Sept. 12; tested, Dec. 3, 4, 5, 1904. Length over all, 17 ft.; clear span, 15 ft.; breadth, 12 ins.; depth over all, 13½ ins.; depth to center of steel, 12 ins.; weight of beam, 2,677 lbs.; mixture, 1:2:4; reinforcement in bottom, two ¾-in. Kahn bars 17 ft. long; reinforcement in bottom, one ¾-in Kahn bar 9 ft. long, bent up slightly; reinforcement in top, two ½-in. Kahn bars 9 ft. inverted; area of steel in tension, 2.34 sq. ins.; area of steel in compression, .76 sq. in.; total area of steel, 3.10 sq. ins.; per cent. of steel, 2.15; compressive strength of concrete, 1,740 lbs. per sq. in.

Time.	Load. lbs.	Deflection. ins.	Remarks.
Dec. 3.			
3.10 P. M.	5629	1-32	
3.50 "	11398	3-16	
4.20 "	15287	3-8	
Dec. 5.	Nothing done.	Sunday.	
Dec. 6.			
8.00 A. M.	15287	3-8	
8.30 "	18100	3-8	
9.00 "	21688	15-32	Hair cracks appearing
9.30 "	24058	5-8	
9.55 "	29943	7-8	
10.05 "	28934	1	
10.10 "	29914	1¼	
10.15 "	30878	1-11-16	
10.25 "	....		Failed.

Dimensions, etc., shown in Fig. 8

BEAM B.—Built Sept. 12; tested, Dec. 5, 6, 1904. Length over all, 17 ft.; clear span, 15 ft.; breadth, 16 ins.; depth over all, 17½ ins.; depth to center of steel, 16 ins.; reinforcement in bottom, two 1-in. Kahn bars 17 ft. long; reinforcement in bottom, one ¾-in. Kahn bar 9 ft. long, bent slightly upwards; area of steel, 3.62 sq. ins. or 1.41%; weight of beam, 4,600 lbs.; mixture, 1:2:4; compressive strength of concrete, 1,740 lbs. per sq. in.

Time.	Load. lbs.	Deflection. ins.	Remarks.
Dec. 5.			
2.00 P. M.	10417	1-16	
2.30 "	15189	3-32	
3.20 "	22802	7-32	
4.10 "	27607	9-32	
4.45 "	31487	11-32	One hair crack on bottom of beam under each bent bar.
Dec. 6.			
8.30 A. M.	31487	11-32	
9.35 "	33403	11-32	Two more hair cracks appeared.
10.50 "	38190	11-32	
12.45 P. M.	45082	15-32	
1.30 "	47817	3-4	Two more hair cracks appeared nearer bearings.
2.10 "	50000	7-8	
3.10 "	54735	1–11-32	
	55727	1– 7-16	
	56712	1–19-32	
3.50 "	57696	1–11-16	
	58675	1–31-32	
4.15 "	59906	2	
5.00 "	60911	2–11-32	Beam overturned.

Dimensions, etc., see Fig. 8.

BEAM A.—Built Sept. 13, 1904; tested, Dec. 7–14, 1904. Length over all, 17 ft.; clear span, 15 ft.; breadth, 16 ins.; depth over all, 17½ ins.; depth to center of steel, 16 ins.; reinforcement in bottom, two 1-in. Kahn bars 17 ft. long; reinforcement in center, one ¾-in. Kahn bar 9 ft. long, bent up slightly; reinforcement in top, two ¾-in. Kahn bars 9 ft. long, inverted; weight of beam, 4,600 lbs.; mixture, 1:2:4; area steel in tension, 3.62 or 1.41%; area steel in compression, 1.56 or .60% ; total steel, 5.18 or 2.10%; compressive strength of concrete, 1,740 lbs. per sq. in.

Time.	Loads. lbs.	Deflection. in.	Remarks.
Dec. 7:			
9.25 A. M.			Started.
10.45 "	10168	1-16	
11.40 "	15937	3-32	

Time	Loads. lbs.	Deflection. in.	Remarks.
2.25 P. M.	20769	5-32	
3.10 "	25632	3-16	
3.25 "	27617	3-16	
3.55 "	31548	3-16	
4.30 "	33561	3-16	
4.45 "	35477	7-32	
5.00 "	37458	7-32	Two faint hair cracks, one at each end of bent bar in center; beam started to overturn, bearings sinking unequally.

Dec. 8: Unloaded and straightened.

No deflection observable, then began loading.

Dec. 9:

8.30 A. M.	37458	7-32	
9.45 "	40839	7-32	
10.35 "	44723	1-4	Four hair cracks (2 more) on each side of center.
11.25 "	50000	5-16	Rain stopped, loading beam overturned, due to unequal settling of foundations.
	52693		

Dec. 11:

	52962	3-32	Set in beam.
	54945	13-32	
	60856	5-8	Beam overturned.

Foundations again settling unequally, beam straightened, one hair crack in center, 2, 3 ft. 6 ins. on either side of center of beam; $\frac{3}{8}$-in deflection set in beam. Foundations releveled bearing area increased and beam reloaded.

Dec. 12: Sunday—Nothing done.

Dec. 13:

11.15 A. M. 60856 3-8 Set in beam.

Several hair cracks from top $\frac{1}{4}$-in. opening traveling off in both directions horizontally, middle each $8\frac{1}{2}$ ins. from top.

63811 Two more hair cracks appeared on either side of center line.

Time.	Loads. lbs.	Deflection. in.	Remarks
	66021	3-4	
3.45 P. M.	74941	1-1-8	
	75000		One crack 18 ins. from center line, 9 ins. from top.
			One crack 36 ins. from center line, 11 inches from top.
			One crack 56 ins. from center line, 7 inches from top.
5.00 P. M.	80000	1-3-8	

Time.	Loads. lbs.	Deflection. in.	Remarks.
Dec. 14:			
8.00 A. M.	80000	1–3-4	
	81010	1–13-16	
	82005	1–13-16	
	83005	1– 7-8	
	83977	1– 7-8	
11.30 A. M.	85400	1– 7-8	
12.00 Noon.	87385	2– 1-32	
1.25 P. M.	90362	2– 5-8	
2.15 "	93269	3– 1-8	
2.30 "	94074	3– 5-16	
2.40 "	94512		Failed
Weight beam	4600		
Total load,	99112		

FIG. 10.—View of Kahn Beam A Under Load

Kahn System Hollow Tile Floor Construction.—Built Sept. 21, tested Nov. 30, Dec. 1, 2, 1904. Length over all, 18 ft. Clear span 16 ft. 6 ins. Width, 5 ft. 8 ins. Depth, 10 ins. Tile, 10 x 12 ins. Beam joists, five, 4 x 10 ins., 18 ft. long, 1′ 4″ centers.

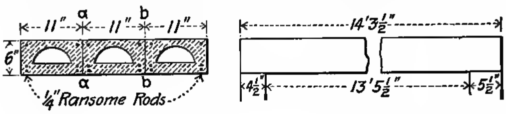
Reinforcement, each joist, one $\frac{3}{4}$-in. Kahn bar, 18 ft. long. Mixture, 1 : 3 : 5. Area steel, each joist, 0.78 in. or 2.30 per cent. Weight of slab, 5,800-lbs.

FIG. 11.—View of Kahn Hollow Tile Floor After Failure.

Time.	Loads. lbs.	Deflection. ins.		Remarks.
Nov. 30:				
4.10 P. M.	12457	n. 3-32	s. 3-32	
4.45 "	18300	1-8	3-32	
5.10 "	22200	1-2	3-8	Hair cracks across center exactly.
5.30 "	25132	5-8	3-8	
Dec. 1:				
8.30 A. M.	25132	3-4	9-16	
5.30 "	25132	3-4	21-32	
Dec. 2:				
8.30 A. M.	25132	3-4	23-32	
11.25 "	25132	25-32	3-4	
11.50 "	34634	2—1-2		Two vertical cracks appeared 3 ins off center line on either side.

11.55 A. M. 35611 Concrete commenced to crush on top over last cracks loading stopped, beam kept cracking and slowly deflected until it failed at 12.15 (20 minutes) with center cracks opening up and another 7 ft. off centre line concrete at center crushing out and a crack running along line of steel from center to right three feet. Breaking load 500 lbs. per sq. foot. The dimensions of slab are shown in Fig. 8, page 24, Fig. 11 shows floor after failure.

Siegwart Floor.—Length over all 14 ft. $3\frac{1}{2}$ ins., clear span 13 ft. $5\frac{1}{2}$ ins., depth 6 ins., width of slab 33 ins.



Time.	Load. lbs.	Deflection. in.	Remarks.
8.30 A. M.	2901	1-8	
9.15 "	5484	5-16	
9.25 "	8409	1-2	Hair cracks well distributed along bottom beam.
	10378	13-16	
	11366	7-8	
10.05 "	15313	1—23-32	
	16284	2—3-4	
10.15 "	16831		Failed.

This floor slab was composed of beams made according to Siegwart System; in above sketch the slab is seen to be composed of three slabs 11 x 6 ins. in section, and reinforced with rods according to Hennebique System without shear straps. The beams are cast around cores (core openings shown in sketch), the steel being placed in position and the concrete cast around it; the cores are withdrawn and the beams feathered apart at the points indicated. These beams were made in New York, and were shipped by express when 60 days old to the exhibit, where they were placed in position and the joints grouted. A load of bags of sand was placed on the floor (100 lbs. per sq. ft.) and remained there until the close of the Exposition, when it was loaded with pig iron to destruction, the beams being about 6 months old. The idea of this system is to make the beams for certain loads and spans and carry them in stock as steel I-beams are carried, shipping on order.

Cantilever.—This is shown in Fig. 12 and was built to illustrate the flexibility of reinforced concrete, the dimensions and rein-

forcement are shown in Figs. 13, 14 and 15. The stairway hung free and led to the top which was a walk; this was in service during the Exposition.

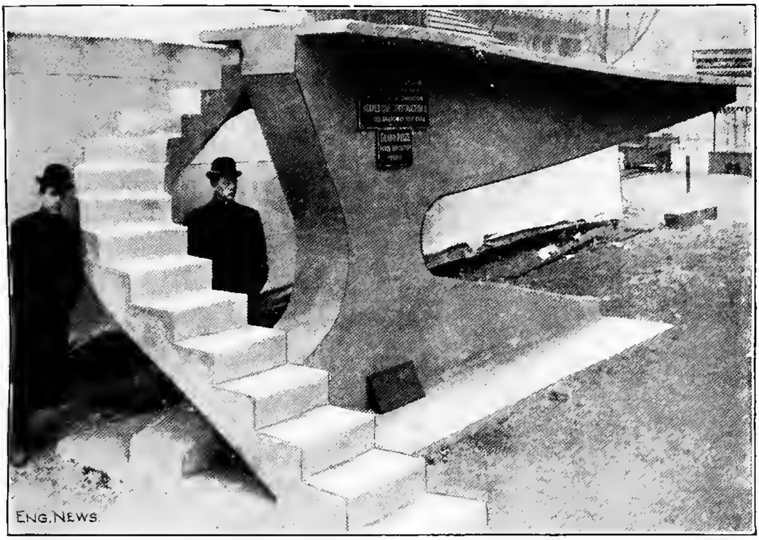
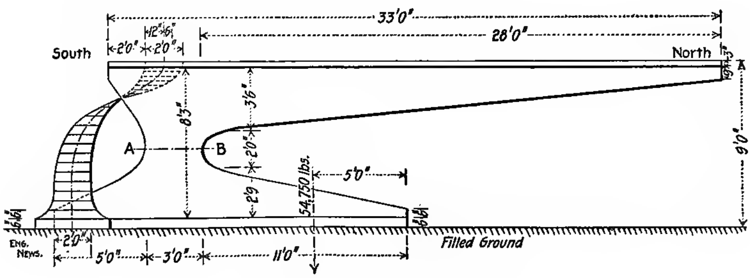


FIG. 12.—View of Reinforced Concrete Cantilever Tested to Destruction.

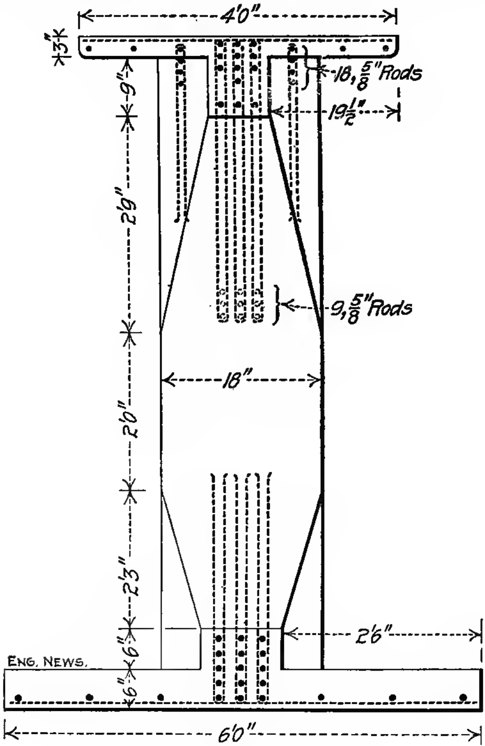
The cantilever was built, as was discovered afterwards, over a wooden box drain and the settlement of the foundation caused the cantilever to tilt towards the outer end.



Side Elevation.

FIG. 13

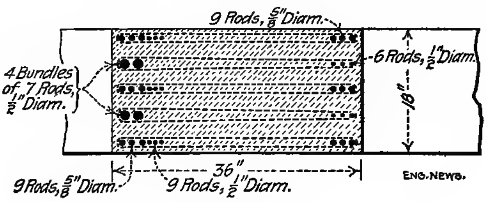
The forms, instead of being removed gradually, were quickly removed, and the sudden application of the load caused a strain



End Elevation, North.

FIG. 14.

which cracked the cantilever at the shank on the left-hand side. The props were restored and the cantilever washed with neat



Section A-B.

FIG 15

cement. The props were then gradually removed and the cantilever remained unchanged until tested with pig iron. The application of this load caused the cracks to open at left side of shank and the cantilever collapsed. As bars of the requisite size were not available a bundle of smaller rods was substituted; the shear members were insufficient to hold the cantilever and it pulled

FIG. 16.—View Showing Failure of Reinforced Concrete Cantilever

apart at the left shank and failed as shown in Fig. 16 before the compressive resistance of the concrete in the right center section of the shank had been reached. The loading was as follows:

Loads. lbs.	Deflection. in.	Remarks
3060	1-16	
9845	1-4	
13735	11-32	
14760		Hair crack appeared.
17680	1-8	Opening at center 11-16 in. at outer end.
20607		Failed 4-11-16 in. extension at the center.

Besides these, tests were made of cement shingles, concrete sewer pipes, cement bricks and hollow blocks.

The Collective Portland Cement Exhibit and Model Testing Laboratory was assembled with a view of exploiting the American Portland Cement Industry and not with a view of advertising any particular process, plant or product. It was highly beneficial in disseminating a better knowledge of the proper methods of testing and of the nature, uses and properties of Portland cement; and in recognition of this fact it received two grand prizes, the highest awards of the Exposition.*

It is to be regretted that the time available for the experimental work was not longer, so that much more data could have been obtained.

It is, however, a matter of gratification to all those connected with this exhibit that the work thus started will be continued under the direction of the United States Government, the Joint Committee on Concrete and Reinforced Concrete, and other interested persons, and it is to be hoped that the exhaustive series of investigations of structural materials which have been planned under the direction of the National Advisory Board on Fuels and Structural Materials may be successfully carried out thereby supplying information of inestimable value to the engineering profession.

*The Collective Portland Cement Exhibit was awarded a Grand Prize (see page 2 The Model Testing Laboratory received a second Grand Prize.